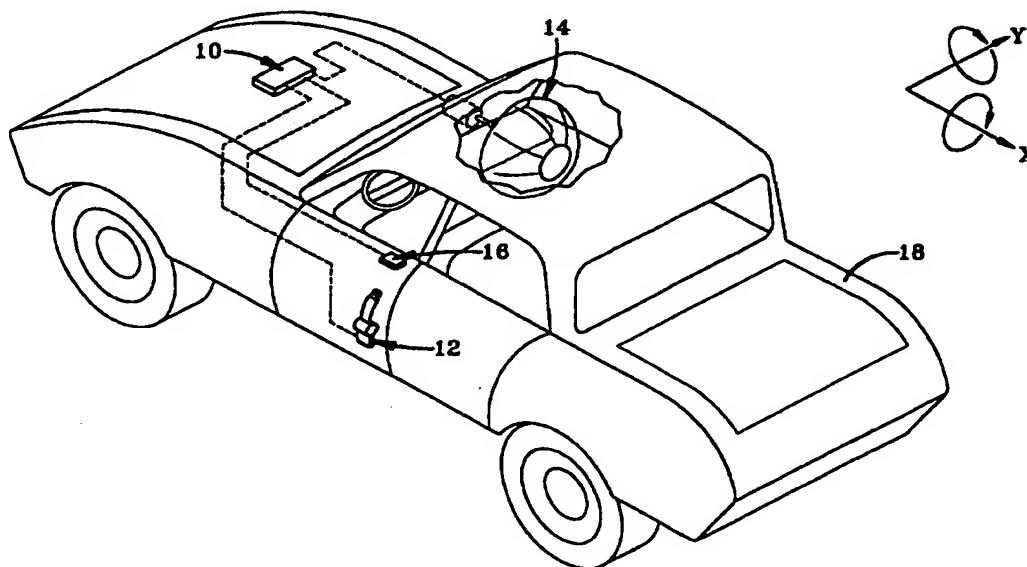




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(21) International Application Number: PCT/US97/07038 (22) International Filing Date: 25 April 1997 (25.04.97) (30) Priority Data: 673,760 24 June 1996 (24.06.96) US (71) Applicant: BREED AUTOMOTIVE TECHNOLOGY, INC. [US/US]; P.O. Box 33050, Lakeland, FL 33807-3050 (US). (72) Inventors: HALASZ, Peter, Trancred; 5236 East 14th Street, Brownsville, TX 78521 (US). HUSBY, Harald, Snorre; 5625 Emerald Ridge Boulevard, Lakeland, FL 33813 (US). (74) Agent: DRAYER, Lonnie, R.; Breed Automotive Technology, Inc., P.O. Box 33050, Lakeland, FL 33807-3050 (US).		(81) Designated States: CA, JP, KR, MX, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: CONTROLLER FOR VEHICULAR SAFETY DEVICE**(57) Abstract**

A control device (10) selectively actuates at least one vehicular safety device such as a seat belt pretensioning mechanism (12), an airbag (14), an automatic roll-over bar or a mechanical door lock (16) comprising a sensor stage (20) to sense a plurality of parameters including acceleration, pitch angle and roll angle of a vehicle (18) and to generate a corresponding plurality of digital signals representing each such parameter and a control stage (22) including circuitry to receive the plurality of digital signals and to generate a control signal corresponding to each such parameter when the corresponding digital signal exceeds a predetermined value, and a safety device actuator including circuitry to receive the control signals and to generate a corresponding actuator signal to actuate the corresponding vehicular safety device.

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CONTROLLER FOR VEHICULAR SAFETY DEVICE

BACKGROUND OF THE INVENTION

5 This invention relates to a control device to selectively actuate at least one vehicular safety device when a sudden change in acceleration, pitch angle or roll angle of a vehicle is detected.

 Accelerometers that measure pitch and roll angles
10 along a predetermined axis and produce signals representative of such measurements are well known in the art. Likewise, filtering, digitizing, formulating and analyzing the accelerometer signals to assess whether certain action should be taken is also known.
15 These concepts have been disclosed in numerous patents in the fields of motor vehicle suspension control, motor vehicle body roll compensation, roll-over bar activation systems and seat belt pretension systems.

 Studies indicate that injuries in motor vehicle
20 accidents, especially at high speeds, can be substantially reduced or eliminated by the use of occupant restraint systems. These systems commonly include a seat belt pretensioner assembly which is operable to move a seat belt assembly through a
25 pretensioning stroke to remove slack from the seat belt during abrupt changes in an automobile's position. When the motor vehicle is subjected to a sudden change in position relative to the driving surface, caused either by a roll-over or pitch-over,
30 the seat belt pretensioner is actuated to tightly restrain the occupants in a position to minimize

movement and prevent contact between the occupants and the automobile interior such as the roof, windshield, steering wheel, and side doors. Since an important element of such protective systems is the sensing
5 system which activates the seat belt pretensioner mechanism, the position of the motor vehicle relative to the driving surface must be carefully and precisely monitored so that the seat belt pretensioner is activated rapidly and reliably before the occupants
10 suffer substantial injury.

Other occupant safety devices employed in motor vehicles to be actuated upon the prediction of a roll-over or a pitch-over may include an air bag, an automatic roll-over bar and an automatic door lock.

15 US 5 102 162 teaches a suspension control apparatus that operates to maintain a level attitude during cornering and turning by computing and map-retrieving from output signals of a vehicle speed sensor and output signals of a yaw angular velocity
20 sensor for detecting angular velocity about a yaw axis of the vehicle.

US 5 471 388 discloses a method and apparatus for preventing vehicle handling instabilities, in which a vehicle yaw angular velocity required value is formed
25 from measured quantities (vehicle velocity, steering wheel angle).

US 4 549 277 relates to a multiple sensor inclination measuring system which includes a plurality of single and dual axis inclination sensors,
30 each sensor including a bridge circuit for generating

a signal or pair of signals, each signal having a voltage which is proportional to the degree of inclination of the sensor, and an analog-to-digital convertor to convert the signal to a digital word
5 having a binary value representative of the tilt of the sensor.

US 4 679 808 describes a system for estimating the state of a controlled vehicle's motion which has a steering wheel angle sensor, a vehicle speed sensor, a
10 sensor for sensing a first motion variable such as a yaw rate, a sensor for sensing a second motion variable such as a yaw acceleration, and a processing unit such as a microcomputer.

US 5 161 816 teaches a suspension control
15 apparatus for a vehicle having at least one shock absorber with a controllable damping force. The suspension control apparatus includes a roll angular velocity sensor for detecting angular velocity about a roll axis of the vehicle, and control means for
20 determining a bumpy road driving state of the vehicle when an accumulation time exceeds a predetermined accumulation time. The control means adjusts the damping force of the shock absorber during the bumpy road driving state.

25 US 4 712 807 discloses a vehicle having a suspension system which includes an actuator for each wheel, each of which is controllable to provide a variable force between the body and the wheel; a sensor for detecting acceleration of the body and for
30 producing a signal representative thereof, a sensor

for each wheel for detecting load acting between the body and the wheel and for producing a signal representative thereof; and a controller for inputting the signals representative of the acceleration of the body and the load on each wheel, for calculating based thereupon fluctuations in load acting between the wheels and the body, for controlling the actuators to increase or decrease forces provided thereby between the body and the wheels, and for operating by feedback action by comparing the actual fluctuation in the force between the respective wheel and the body as sensed by the load sensor for the wheel with the calculated value therefor, and for bringing the difference between the two values to be zero.

US 5 510 988 relates to a vehicle that has a real time suspension control which requires, as inputs, a set of absolute body modal velocity signals. Accurate estimates of these signals are derived from relative position sensors at the body suspension points by converting the relative vertical position signals from these sensors to relative body modal (e.g. heave, pitch and roll) velocity signals and passing each of these signals through a second order low pass filter including an additional phase inversion for compensation of the 180 degree filter phase lag. Thus, the necessity of absolute body accelerometers is eliminated, for a significant cost reduction.

US 5 510 986 describes a force actuator that is connected between a vehicle body and each vehicle wheel. A position sensor senses displacement between

the vehicle body and each vehicle wheel and provides a position signal indicative thereof. An acceleration sensor senses vertical inertial acceleration of the vehicle body relative to ground at each vehicle wheel and provides an acceleration signal indicative of vertical inertial acceleration of the vehicle body at each vehicle wheel. A controller including a digital signal processor determines a velocity signal based on each acceleration signal. A force actuator control signal at each vehicle wheel is produced which varies as a function of the plurality of modal forces. A drive circuit processes the force actuator signal at each wheel and applies the processed force actuator control signal at each vehicle wheel to the associated force actuator.

US 5 127 667 teaches a method wherein a pitching motion of bouncing, bottoming, bumpy road driving and braking of a vehicle during driving is correctly grasped by computing and map retrieving from output signals of a vehicle speed sensor, output signals of a brake switch and output signals of a pitch angular velocity sensor for detecting angular velocity about a pitch axis of the vehicle; and pitching motion of the vehicle is restrained by the adjusting damping force of shock absorbers of the suspension control apparatus.

US 5 328 256 relates to an anti-skid brake control device that has a control circuit to which signals from a steering angle sensor, a yaw detector, and respective wheel velocity sensors of a motor

vehicle are inputted, an oil pressure actuator controls of the pressure of the braking fluid for respective wheel cylinders based upon target slip rates and measured slip rates for the respective
5 wheels calculated in the control circuit.

US 4 749 926 describes an automatic trim control system designed to be used on power boats equipped with electric or hydraulic actuated trim tabs. The unit senses out of trim conditions in two planes
10 (pitch and roll) and transmits control signals to the electro-mechanical control lines to reposition the trim tab attitudes, thereby reestablishing preset trim conditions as required.

US 5 317 542 teaches a method wherein a ship's attitude parameters, including pitch, roll and heading, provided in the form of synchro signals by redundant sensors, are distributed to various shipboard systems by a synchro selector binary switching tree under the control of a digital
20 processor. The processor also generates dynamic simulations of pitch, roll and heading, which can be distributed to the shipboard systems by the switching tree.

US 4 803 627 discloses a system for vehicle roll control wherein a plurality of actuator assemblies are provided, one corresponding to each one of the vehicle wheels. Each of these actuator assemblies is adapted to increase or decrease the vehicle height at a location corresponding to its corresponding vehicle
25
30

wheel as results of control signals being applied to it.

US 4 693 493 relates a system for vehicle roll control wherein a plurality of actuator assemblies are provided, one corresponding to each one of the vehicle wheels. These actuator assemblies have pressure chambers, and each is adapted to increase or decrease the vehicle height at a location corresponding to its corresponding vehicle wheel as respective results of supplying or discharging of working fluid to or from its pressure chamber. A vehicle speed detector senses the road speed of the vehicle, and a steering angle detector senses the steering angle of the vehicle. A control computer computes a steady state roll angle of the vehicle body from the vehicle speed sensed by the vehicle speed detector and the steering angle sensed by the steering angle detector, and computes a difference value based thereon, the control computer being adapted to control the working fluid supplying and discharging valves.

US 4 807 128 discloses a system for vehicle roll control wherein one actuator assembly is provided corresponding to each vehicle wheel. Each of these actuator assemblies is adapted to increase or decrease the vehicle height at its vehicle wheel as a result of a control signal being supplied. Control means are provided corresponding to the actuator assemblies and serve to supply control signals to them. A vehicle speed detecting means senses road speed, a steering angle detecting means senses steering angle, a means

senses the rate of change of steering angle, and a means detects the actual roll angle of the vehicle body. A computing and control means computes a steady state roll angle of the vehicle body from the vehicle speed and the steering angle, advances the phase of a signal representative of the steady state roll angle to thereby compute a compensating value of roll angle.

US 5 094 478 teaches a convertible motor vehicle with two roll-over bars which can be swivelled into an upwardly directed supporting position. The rollover protection system can be integrated into conventional vehicle concepts in a particularly space-saving and advantageous manner and reduces the risk of injury in the case of a fast, sensor-controlling swinging-up of the rollover bars.

US 5 458 396 discloses a convertible motor vehicle with at least one seat having an extendable roll bar incorporated into an upper portion thereof. Known motion sensors are used to trigger the roll bar and cause a release from its rest position to its operating position.

US 5 492 368 relates to a vehicle seat system for a vehicle seat mounted on the vehicle floor also including a resilient vehicle seat cushion for normally supporting a seated occupant; a lap restraint to cross over the seated occupant to restrain the occupant in the vehicle seat; a belt pretensioner associated with the lap restraint; and a sensor to activate the belt pretensioner when the vehicle

undergoes a displacement condition indicative of a vehicle rollover condition.

US 5 261 506 describes a control device for a passenger safety apparatus wherein the safety apparatus is triggered by a sensor arrangement which responds to a longitudinal and/or transverse acceleration of the motor vehicle. It is also independently triggerable by an additional state-of-motion or moving condition sensor which is configured to recognize a near weightless state of the vehicle.

US 5 364 129 discloses a belt tensioning mechanism that is actuated in response to a vehicle deceleration exceeding a predetermined critical value for retracting the belt buckle. The belt tensioning mechanism includes a sensor for sensing the magnitude of a vehicular deceleration and generating a deceleration signal indicative of a vehicular deceleration exceeded the predetermined critical value.

US 5 295 714 relates a vehicle safety belt system with a gripping means arranged at a webbing section extending between a deflection fitting and a belt retractor.

US 5 288 105 describes a vehicle safety belt pre-tensioning system which includes a slider to which a cable is attached. The slider is affixed to a safety belt buckle and to a cable for pulling the buckle forcibly downward to secure a seat occupant upon occurrence of an emergency condition. A sensor

mechanism activates a trigger upon detecting an emergency condition.

US 4 941 683 teaches a vehicle seat belt tightening system for taking up slack from a seat belt
5 in a high acceleration or deceleration condition to positively restrain a vehicle occupant. In particular, the operation reliability may be improved if the reverse rotation of the seat belt tightening unit is prevented by a ratchet mechanism.

10 US 5 211 423 discloses a vehicle-sensitive belt tensioning mechanism provided for taking up slack in a seat belt in response to a high deceleration condition for restraining the seat occupant against forward excursion. The belt tensioning mechanism includes an
15 inertial sensing device for detecting the deceleration forces.

US 5 127 671 describes a pretensioner system for positively eliminating loosening of a seat belt to effectively restrain a vehicle occupant during vehicle
20 collision. The pretensioner system includes an acceleration sensing device for sensing acceleration of a vehicle.

Despite these numerous devices, the need for a safety device including a sensing mechanism to
25 activate a seat belt pretensioning mechanism or the like when a roll-over or pitch-over condition exists is yet to be developed.

SUMMARY OF THE INVENTION

There is provided in accordance with one aspect of the present invention a control device to activate
5 a seat belt pretensioning mechanism and/or other vehicular safety device in case of a motor vehicle roll-over or pitch-over movement.

There is provided in accordance with another aspect of the present invention logic and a method for
10 predicting roll-overs and pitch-over movements in motor vehicles and for activating vehicular safety devices in response to the predictions.

There is provided in accordance with another aspect of the present invention logic and a method for
15 analyzing signals produced by accelerometers for sensing vehicular attitude to predict roll-overs or pitch-over movements in motor vehicles.

There is provided in accordance with another aspect of the present invention logic and a method for
20 analyzing signals produced by accelerometers for sensing both the X axis (pitch-over) and Y axis (roll-over) in motor vehicles for activating vehicular safety devices based on those signals.

There is provided in accordance with another
25 aspect of the present invention logic and a method for both sensing and/or predicting roll-over or pitch-over movements in motor vehicles and for activating appropriate vehicular safety devices based on either sensing and/or predicting roll-over, or pitch-over
30 movement.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and object of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a vehicle with the control device of the present invention.

Fig. 2 is a block diagram of the control device of the present invention.

Fig. 3 is a family of curves depicting the probability of a roll-over condition as a function of the roll angle and the rate of change of the roll angle.

Fig. 4 is a map of the family of curves depicted in Fig. 3.

Fig. 5 is a family of curves depicting the probability of a pitch-over condition as a function of the pitch angle and the rate of change of the pitch angle.

Fig. 6 is a map of the family of curves depicted in Fig. 5.

Fig. 7 is a flow chart depicting the operation of the control device of the present invention.

Similar reference characters refer to similar parts throughout the several views of the drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in Fig. 1, the present invention relates to a control device generally indicated as 10 to
5 selectively actuate at least one vehicular safety device such as a seat belt pretensioning mechanism 12, an airbag 14 or an automatic door lock 16 of a vehicle 18.

As shown in Fig. 2, the control device 10
10 comprises a sensor means generally indicated as 20 to sense a plurality of parameters including acceleration, pitch and roll angles of the vehicle 18 as defined hereinafter and to generate a corresponding plurality of digital signals representing each such
15 parameter and a control means generally indicated as 22 comprising a control signal generator means including control logic circuitry to receive the plurality of digital signals and to generate a control signal corresponding to each such parameter when the
20 corresponding digital signal exceeds a predetermined value and a safety device actuator signal generator means including actuator logic circuitry to receive the control signals and to generate a corresponding actuator signal to actuate the corresponding vehicular
25 safety device 12, 14, or 16 as described more fully hereinafter.

For convention, an angle of inclination is defined as the rotation of an object with respect to the Earth's surface. Two angles, roll and pitch,
30 completely describe the inclination of an object such

as the vehicle 18 with respect to the Earth's gravitational field. With reference to the control device 10 of the present invention, two single axis micromachined capacitive type accelerometers or a
5 dual-axis tilt sensor such as the Crossbow Technology CXTILTO2 may be used.

As shown in Fig. 1, the pitch angle or inclination of the longitudinal center line of the vehicle 18 relative to the roadway is measured about
10 the X-axis and the roll angle or inclination of the transverse center line of the vehicle 18 is measured about the Y-axis. As described more fully hereinafter, the control device 10 measures pitch and roll angles of inclination and calculates the pitch
15 and roll angle rates of change to predict when the vehicle 18 will rotate through a predetermined arc such as ninety degrees about the X-axis (pitch) or Y-axis (roll) defined as a pitch-over condition and a roll-over condition respectively. These calculations
20 are dependent on several constants which vary with different makes and models of vehicles 12. These constraints include the weight, the center of gravity, the height, width, and length and other characteristics such as acceleration and braking of
25 the vehicle 18.

As previously described, the control device 10 comprises a sensing means and a control means generally indicated as 20 and 22 respectively. As
shown in Fig. 2, the sensing means 20 comprises a
30 first and second sensing element generally indicated

as 24 and 26 respectively, corresponding first or low frequency filter 28 and second or high frequency filter 30, and an A/D converter 32. The first sensing element 24 comprises an X-axis accelerometer 34 and a corresponding conditioning ASIC 36; while, the second sensing element 26 comprises a Y-axis accelerometer 38 and a corresponding conditioning ASIC 40. As previously described, the X-axis accelerometer 34 and the Y-axis accelerometer 38 generate analog signals corresponding to the angular inclination or disposition of the vehicle 18 relative to the roadway. The conditioning ASICs 36 and 40 calibrate the corresponding analog signals from the X-axis accelerometer 34 and the Y-axis accelerometer 38 such as a ratio of 1 G to 1 volt. Of course, as previously mentioned, a dual axis accelerometer is equally suitable. The first and second frequency filters 28, 30 filter the corresponding analog signals from the first and second sensing elements 24 and 26 respectively into a first or low frequency band width such as from between about 10 Hz to about 40 Hz corresponding to or representing the angles of inclination to the X-axis and Y-axis relative to the roadway indicative of the pitch and roll condition of the vehicle 18 respectively and a second or high frequency band width such as from between about 1000 Hz to about 2000 Hz corresponding to or representing acceleration indicative of an impact due to a collision. The low and high frequency analog signals from both the first and second frequency

filters 28 and 30 are digitized by the A/D converter 32.

As shown in Fig. 2, the control means 22 comprises a control signal generator means generally indicated as 42 including a scaling amplifier 44, a first control signal generator comprising a first stage and a second stage indicated as 46 and 48 respectively to receive the first frequency signals from the first and second frequency filters 28 and 30, and a second control signal generator 50 to receive the second frequency signal from the first and second frequency filters 28 and 30, and an actuator signal generator means 52. The scaling amplifier 44 scales and amplifies the digitized signals received from the sensing means 20 corresponding to the pitch and roll angles of inclination along the X-axis and Y-axis respectively. The first stage 46 of the first control signal generator includes logic means to generate a pitch angle signal and a roll angle signal corresponding to the angle of inclination of the vehicle 18 relative to the roadway along the X-axis and Y-axis respectively. The pitch and roll angle signals are fed to the second stage 48 including storage means to store the families of curves shown in Figs. 3 and 5 and the maps shown in Figs. 4 and 6, and means to generate the rate of change of the pitch angle and rate of change of the roll angle. The first control signal generator means further includes logic circuitry to generate a first control signal when either the pitch angle and pitch angle rate each

exceeds a predetermined value indicative of a pitch-over condition or when the roll angle and roll angle rate each exceeds a predetermined value indicative of a roll-over condition by comparing the pitch angle and pitch angle rate to predetermine values of pitch angle and pitch angle rate as depicted by the family of curves of Fig. 3 and the map shown in Fig. 4 and the roll angle and roll angle rate to predetermined values of roll angle rate as depicted by the family of curves of Fig. 5 and the map shown in Fig. 6 respectively.

The actuator signal generator means 52 includes logic means to generate an actuator signal to actuate at least one of the vehicular safety devices 12, 14 or 16 when the first control signal is received from the first control signal generator means.

The second control signal generator means 50 includes logic means to generate a first control signal when the G force sensed by the sensor means 20 exceeds a first predetermined value such as from about 3 Gs to about 5 Gs and a second control signal when the G force sensed by the sensor means 20 exceeds a second predetermined value such as about 50 Gs. The actuator signal generator means 52 further includes logic means to generate a first actuator signal to actuate at least one of the vehicular safety devices 12, 14 or 16 when the first control signal is received from the second control signal generator means 50 and to generate a second actuator signal to actuate at least one of the other vehicular safety devices 12, 14

and 16 when the second control signal from the second control signal generator means 50 is received.

As shown in Figs. 2 and 7, the values of the G-forces measured along the X-axis and Y-axis as well as the
5 pitch and roll angles together with the pitch and roll angle rates along the X-axis and Y-axis may be fed to an optional output data and/or event recording device (not shown). The control device 10 may further
10 include a system reset means to clear faults and reset the control device 10 upon ignition.

Although the invention has been described in its preferred embodiment, it is understood that the present disclosure of the preferred embodiment may be
15 changed in details of construction and the combination and arrangement of elements may be departed from without diminishing the scope of the invention as hereinafter claimed.

CLAIMS:

1. A control device (10) to selectively actuate at least one vehicular safety device comprising a
5 sensor means (20) to sense the pitch angle and roll angle of a vehicle and to generate a corresponding digital signal representing each such angle and a control means (22) including circuitry to receive said digital signals and to generate a control signal when
10 either said digital signal exceeds a predetermined value and an actuator means (52) including circuitry to receive said control signal and to generate an actuator signal in response thereto to actuate the vehicular safety device.

15

2. A control device (10) to selectively actuate at least one vehicular safety device according to claim 1 wherein the sensor means (20) includes a first sensing element (24) having an X-axis accelerometer
20 (34) and a second sensing element (26) having a Y-axis accelerometer (38); the X-axis accelerometer and the Y-axis accelerometer generate analog signals corresponding to the angular inclination or disposition of the vehicle relative to the roadway;
25 the pitch angle or inclination of the longitudinal center line of the vehicle relative to the roadway is measured about an X-axis and the roll angle or inclination of the transverse center line of the vehicle relative to the roadway is measured about a
30 Y-axis; the control device measures pitch and roll

angles of inclination and calculates the pitch and roll angle rates of change to predict when the vehicle will rotate through a predetermined arc such as ninety degrees about the X-axis (pitch) or Y-axis (roll) defined as a pitch-over condition and a roll-over condition respectively.

3. A control device (10) to selectively actuate at least one vehicular safety device according to claim 2 wherein the sensor means (20) includes first and second frequency filters (28, 30) to selectively filter the corresponding analog signals from the first and second sensing elements (24, 26) into a first frequency band width corresponding to or representing the angles of inclination to the X-axis and Y-axis relative to the roadway indicative of the pitch and roll condition of the vehicle and a second band width corresponding to or representing acceleration indicative of an impact.

20

4. A control device (10) to selectively actuate at least one vehicular safety device according to claim 3 wherein the sensor means (20) includes an A/D converter (32) which receives the first and second frequency analog signals from the first and second frequency filters (28, 30) and converts the first and second frequency analog signals into digital signals.

5. A control device (10) to selectively actuate at least one vehicular safety device according to claim

1 wherein the control means (22) includes a control
signal generator means (42) having a first control
signal generators to receive the first frequency
signals from the first and second frequency filters
5 (28, 30); and a second control signal generator means
(50) to receive the second frequency signal from the
first and second frequency filters; the first control
signal generator including a first stage (46) and a
second stage (48).

10

6. A control device (10) to selectively actuate
at least one vehicular safety device according to
claim 5 wherein the second control signal generator
means (50) includes logic means to generate a first
15 control signal when the G force sensed by the sensor
means (20) exceeds a first predetermined value.

7. A control device (10) to selectively actuate
at least one vehicular safety device according to
20 claim 5 wherein the second control signal generator
means (50) includes logic means to generate a second
control signal when the G force sensed by the sensor
means (20) exceeds a second predetermined value.

25 8. A control device (10) to selectively actuate
at least one vehicular safety device according to
claim 1 wherein the control means (22) includes an
actuator signal generator (52).

30 9. A control device (10) to selectively actuate

at least one vehicular safety device according to
claim 8 wherein the actuator signal generator means
(52) includes logic means (52) to generate an actuator
signal to actuate at least one of the vehicular safety
5 devices when the first control signal is received from
the first control signal generator means.

10. A control device (10) to selectively actuate
at least one vehicular safety device according to
10 claim 8 wherein the actuator signal generator means
(52) further includes logic means to generate a first
actuator signal when the first control signal is
received from the second control signal generator
means (50) to generate a second actuator signal to
15 actuate at least one of the other vehicular safety
devices when the second control signal from the second
control signal generator means is received.

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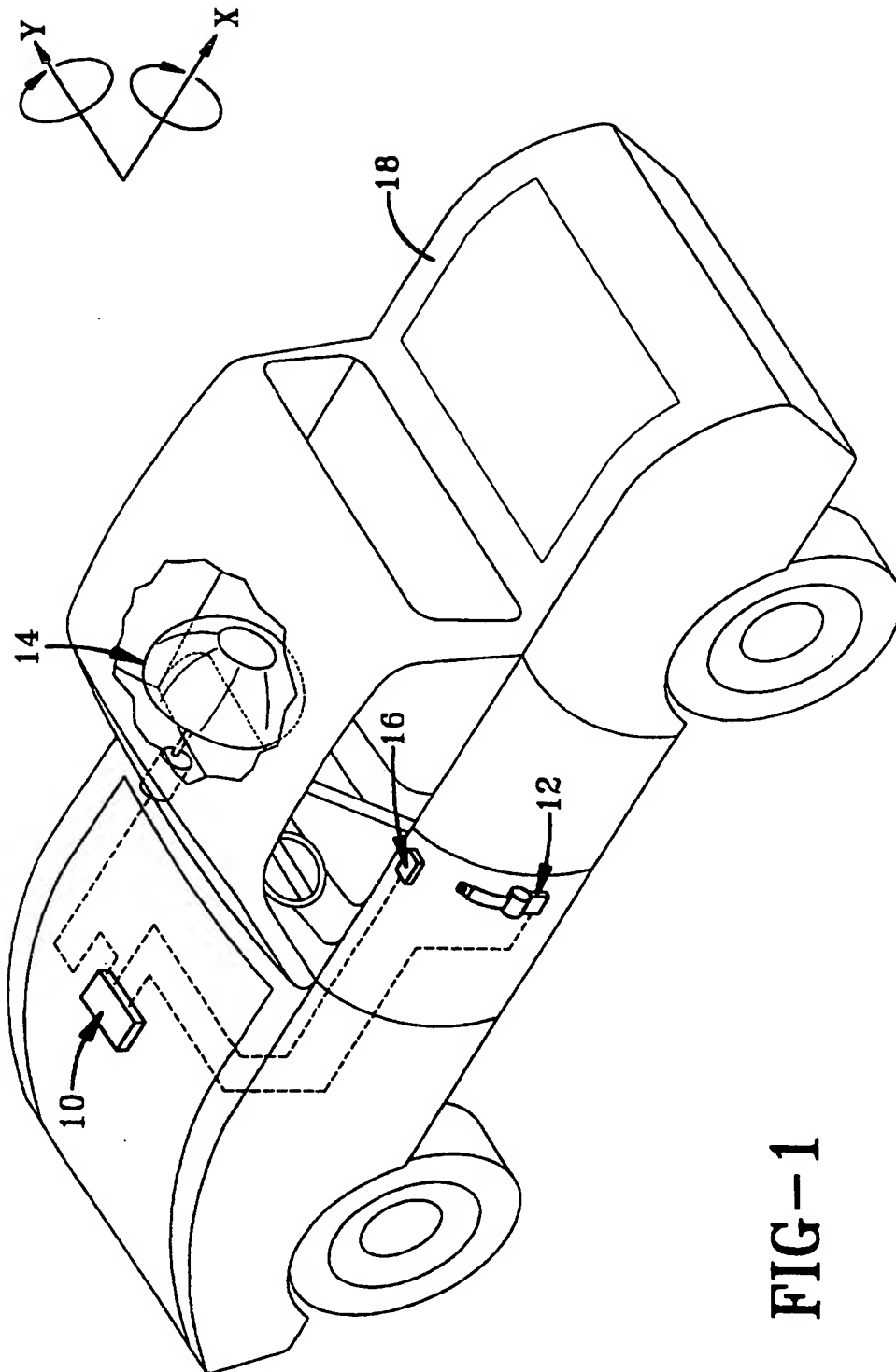
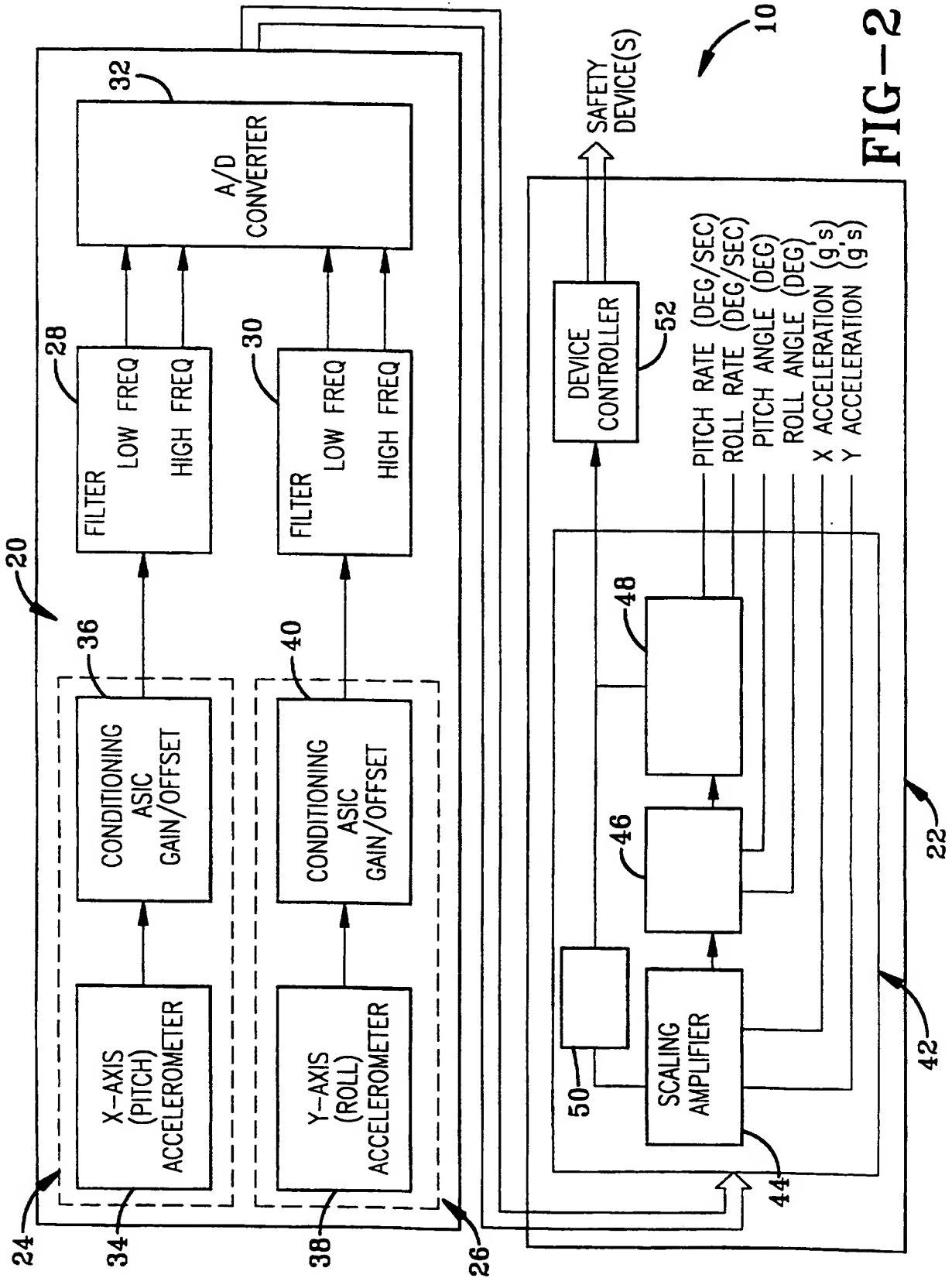
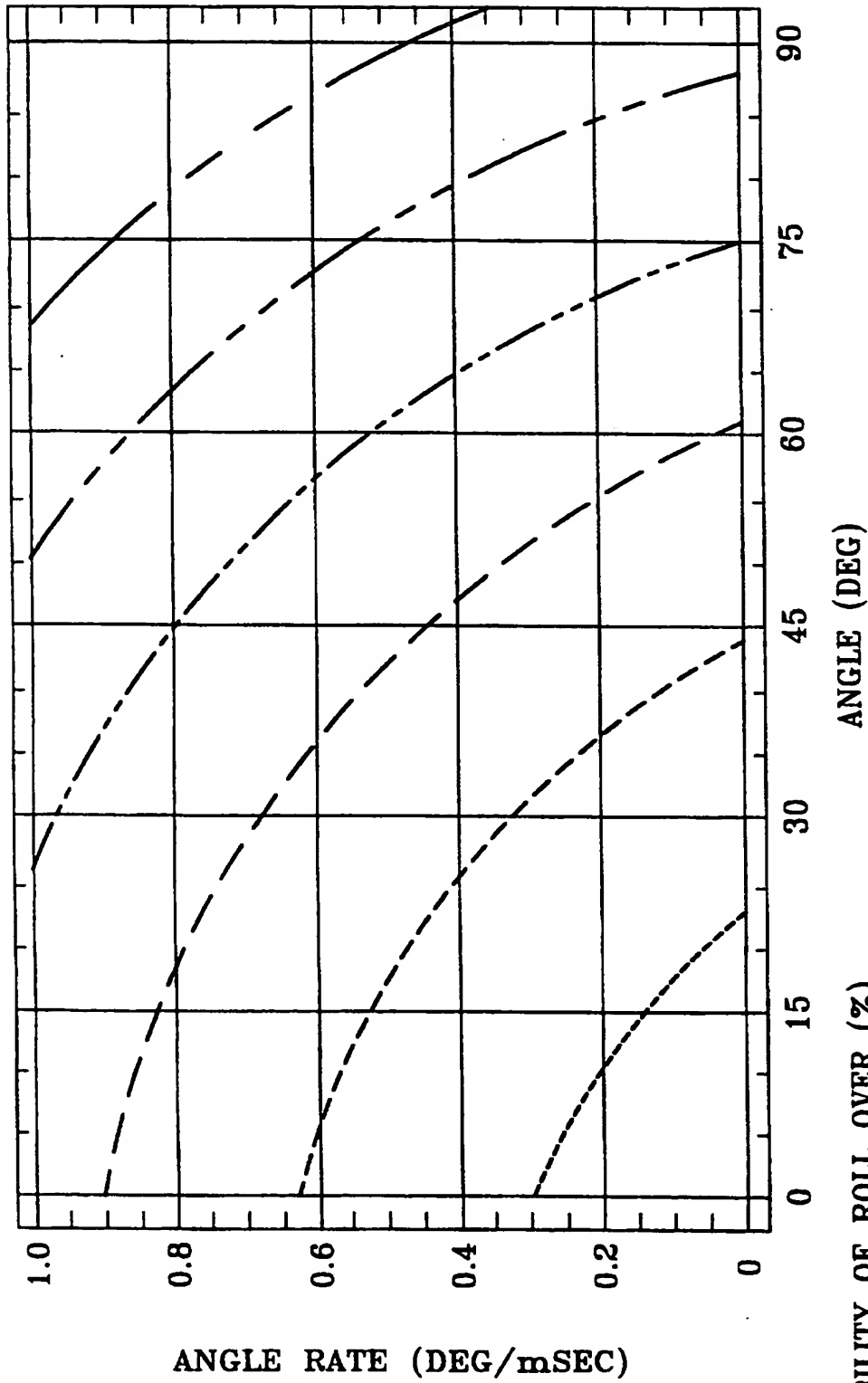


FIG-1

2/7



3/7



PROBABILITY OF ROLL OVER (%)

0.0	---
20.0	---
40.0	---
60.0	---
80.0	---
100.0	---

FIG-3

4/7

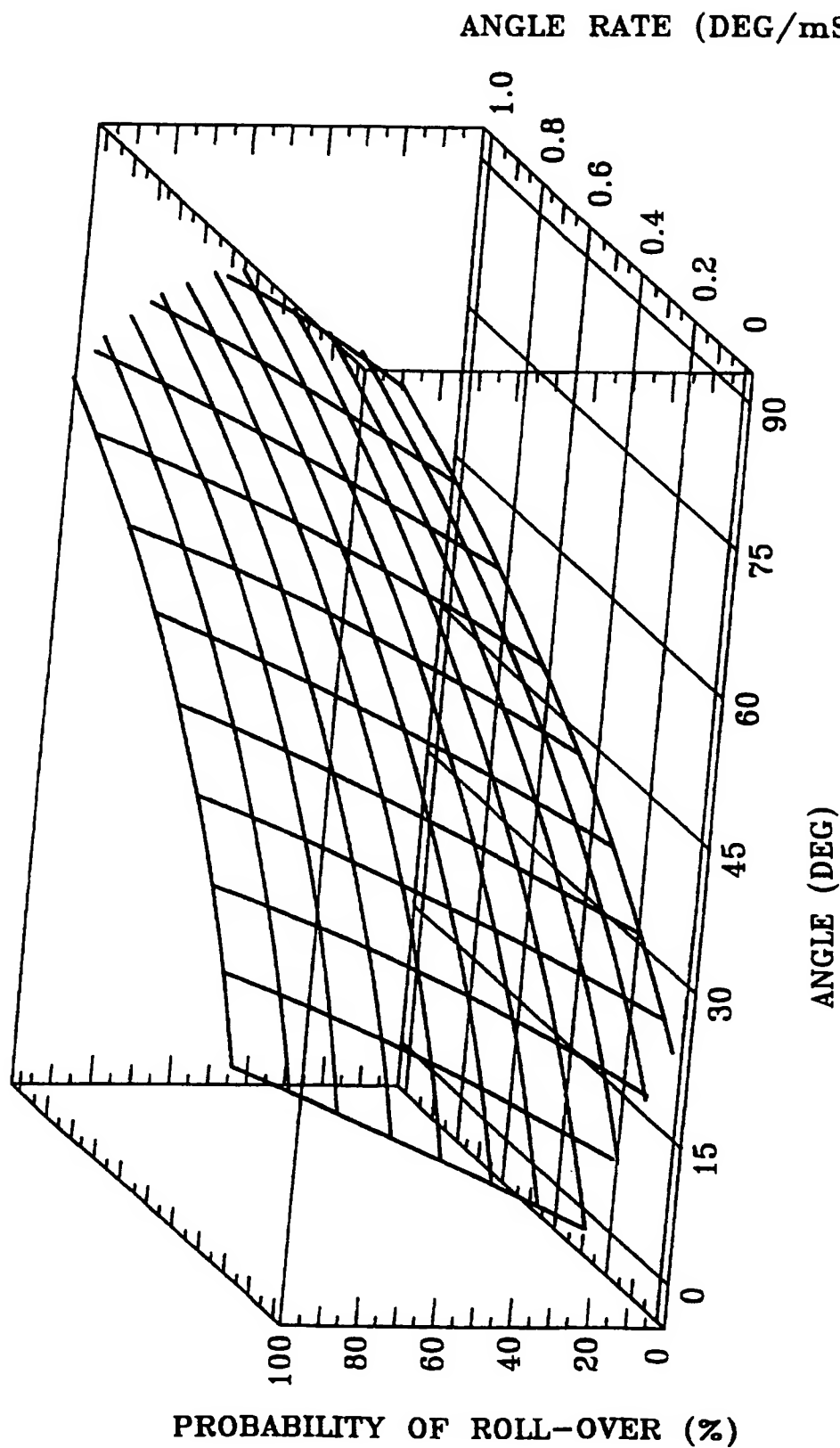


FIG-4

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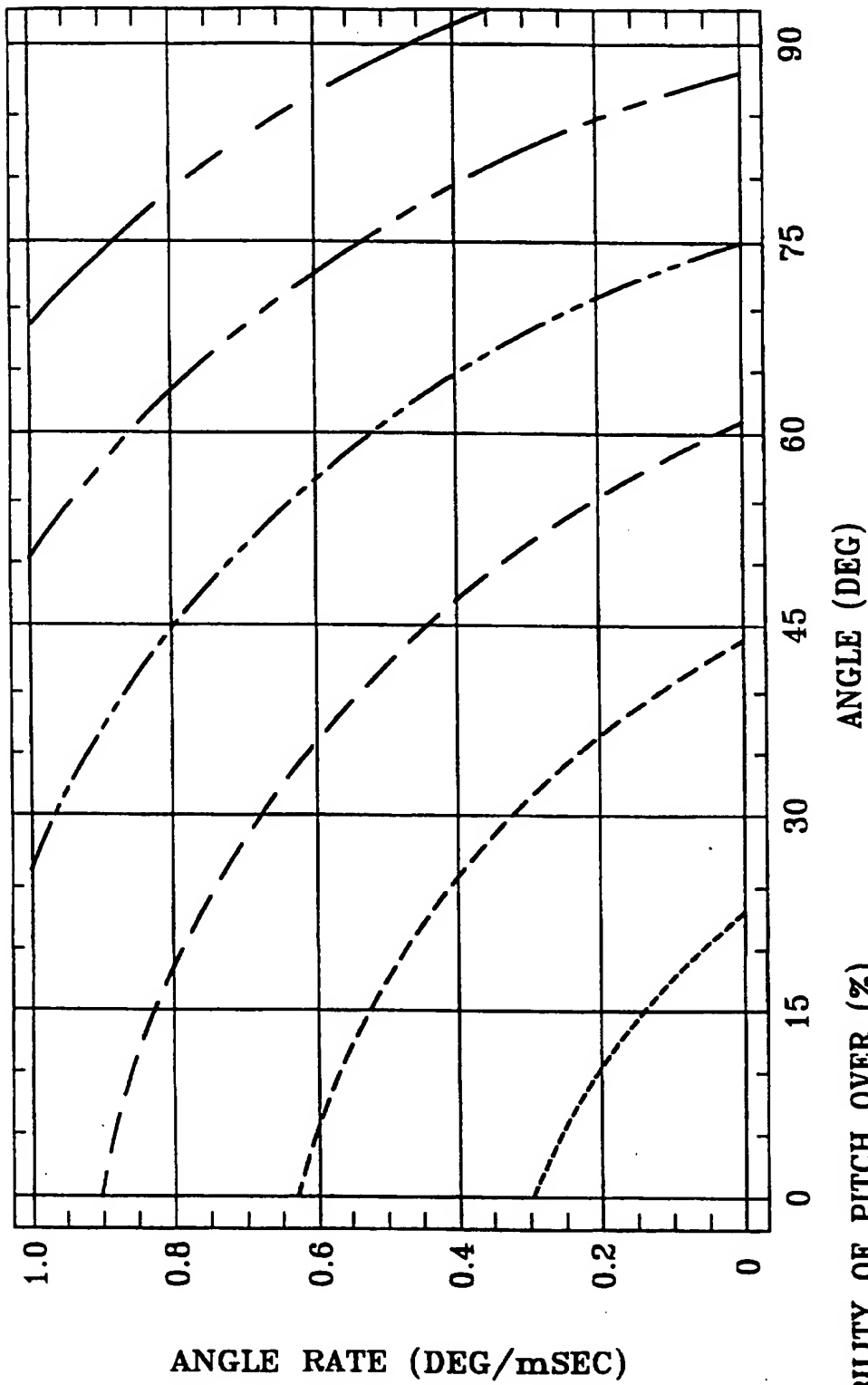


FIG-5

0.0	-----
20.0	-----
40.0	-----
60.0	-----
80.0	-----
100.0	-----

6/7

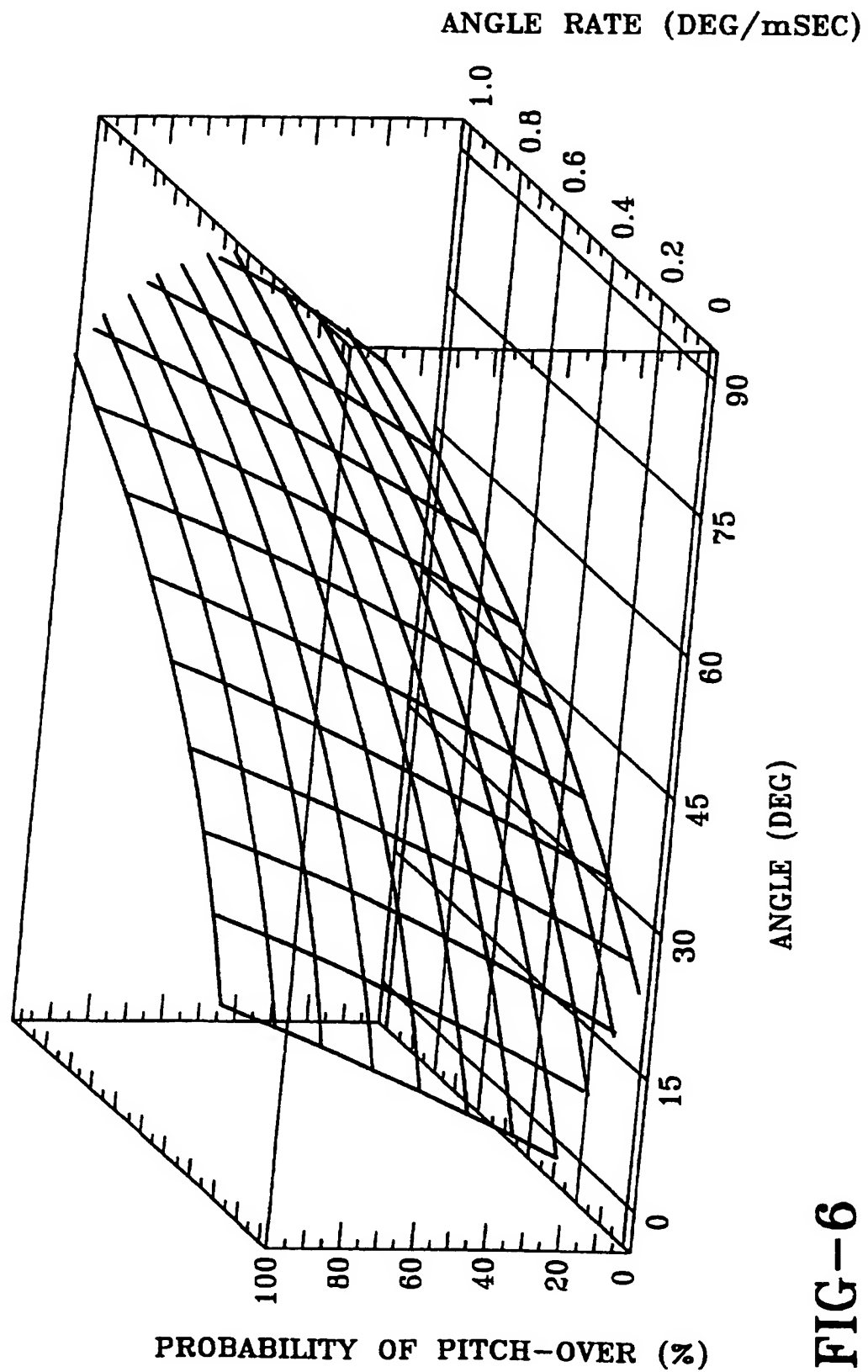


FIG-6

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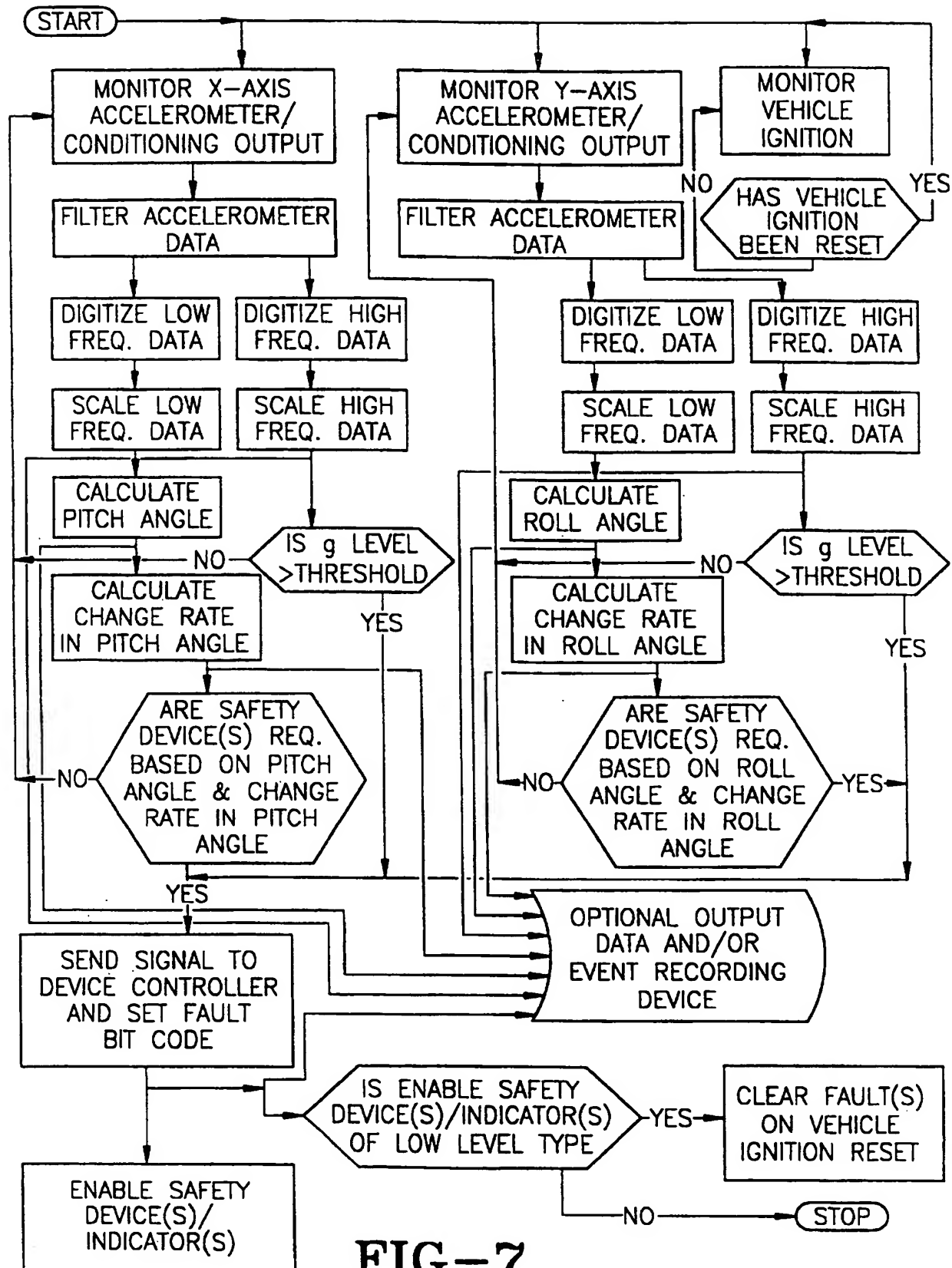


FIG-7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/07038

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B60R 21/00

US CL :364/424.055; 307/10.1; 280/735; 180/282

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/424.055, 424.056, 424.057, 559, 566; 307/10.1; 280/734, 735, 801.1; 180/268, 271, 281, 282

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,784,237 A (CONDNE et al) 15 November 1988, col. 1, lines 32 + and 61 + ; col. 4, lines 3-68; col. 5, lines 1 + .	1-10
Y	US 3,833,084 A (HENDERSON et al) 03 September 1974, col. 1, lines 4 + and 23 + ; col. 5, lines 2-54; claim 3.	1-2, 8-9
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A		3-7, 10
Y	US 5,446,658 A (PASTOR et al) 29 August 1995, Figures 3 and 5; col. 2, lines 35-68.	1-2, 8-9
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A		3-7, 10
A	US 3,034,097 A (ENGLISH et al) 08 May 1962, entire document.	1-10
A	US 4,549,277 A (BRUNSON et al) 22 October 1985, entire document.	1-10

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/07038

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,029,473 A (JOST et al) 09 July 1991, entire document.	1-10
A	US 5,261,506 A (JOST) 16 November 1993, entire document.	1-10

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